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☐	L4	(inter near2 satellite) and (time near2 hop$3)	3
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☐	L2	=19991008	18318713
☐	L1	(time near2 hop$4) same (satellite)	31

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L4: Entry 1 of 3   File: USPT   May 6, 2003

DOCUMENT-IDENTIFIER: US 6560450 B1
TITLE: Satellite communications routing and addressing method
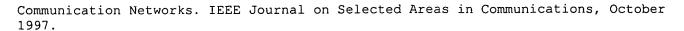
Brief Summary Text (5):
Communications systems are now being developed in which the system nodes comprise a
constellation of non-geostationary satellites, e.g. low earth orbit (LEO)
satellites. These systems comprise a ground segment incorporating e.g. ground
stations, gateways and user terminals, and a space segment comprising the satellite
network in which each satellite functions as a switch or a router. It will be
appreciated that the topology of such a system is constantly changing as the
satellites move relative to the earth's surface and to each other. In a proposed
system, a large number of satellite communications nodes are placed into
circumpolar orbits, there being a number of satellites evenly distributed around
each orbit so as to provide coverage of much or all of the global surface.
Communication with the ground is effected via up-links and down-links to ground
stations. Movement of the satellites relative to the ground stations is
accommodated by appropriate hand-over procedures. A typical system of this type
comprises two hundred and eighty eight satellites divided into twelve orbital
planes for the initial phase, this phase being planned to cover 95% of the
landmass. Further satellites may be added in the future. The system embodies inter-
satellite links (ISL) not only for intra-plane and inter-plane node communications,
but also at the cross-seam. Some of these ISLs can be turned on or off at
appropriate times. The space segment of the satellite network results in a geodesic
topology network that provides good tolerance to faults and congestion and has a
symmetrical structure.

Brief Summary Text (7):
A particular problem in such a system is that of routing traffic between two ground
based terminals via a succession of satellite nodes. It will be appreciated that,
routing in a network that is changing topology rapidly because the satellite
coverage is time varying, the inter-satellite links are dynamic. Depending on the
satellite position, some of these links can be off or on, and some are always on.
It will also be appreciated that, because the satellites are moving thus constantly
changing the network topology in a complex manner, a routing table based routing
would require continual updates. Moreover, an accurate routing would require every
satellite to be well aware of the topological changes in the space segment. This
could be done by storing all the information in the satellites, but this would be
very costly since the topological changes are extremely complex even if there are
in principle predictable and a large amount of information storage and processing
would thus be required. Another way would be to require each satellite to send
topological information to its neighbours (for example). This also would be very
costly in terms of overheads due to the fast pace at which the topology is
changing.

Brief Summary Text (9):
A discussion of satellite communications routing techniques is provided by Markus
Werner et al, ATM-Based Routing in LEO/MEO Satellite Networks with Inter-satellite
Links. IEEE Journal on Selected Areas in Communications, January 1997, and by
Markus Werner, A Dynamic Routing Concept for ATM-Based Satellite Personal

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Communication Networks. IEEE Journal on Selected Areas in Communications, October 1997.

Brief Summary Text (22):
According to another aspect of the invention there is provided a method of routing of packet communications traffic at a satellite node in a communications network comprising a constellation of non-geostationary satellites servicing a plurality of ground based cells via up-links and down-links, there being inter-satellite communications links between adjacent satellites, the method comprising providing a said packet with a destination address incorporating binary Gray codes corresponding to the destination cell of that packet, and, at a said node, comparing the Gray code address of that packet with address codes corresponding to the current position of the satellite so as to provide a simple determination of the direction in which that packet should be routed to an adjacent satellite over a said inter-satellite link.

Detailed Description Text (4):
In the system of FIG. 1, all the satellites have substantially identical characteristics in terms of capacity of the links and processing capabilities. Each satellite 11 behaves as an independent switch in the sky, connected to the earth or ground segment via the up-links 13 and down-links 14 (see FIG. 1a) and to adjacent satellites via the inter-satellite links (ISL) 15, 16. There are three kinds of ISL: intra-plane links 15, inter-plane links 16, and a variation of these latter that are referred to as cross-seam links.

Detailed Description Text (5):
In the network of FIGS. 1 and 1a, here are two intra-plane links 15 per satellite 11, one pointing forward and one backward to the adjacent satellites 11a and 11b in the same orbital plane 12. Both these intra-plane links are in service permanently. There are two further types of inter-satellite links, these being termed inter-plane and cross seam links respectively. As shown in FIG. 1a, the inter-plane links 16 are directed towards the neighbouring satellites in adjacent orbits at each side of the orbital plane 12; that is, for a constellation with near pole orbits, there would be two links 16c and 16d to neighbours 11c and 11d in the West direction and two links 16e and 16f to neighbours 11e and 11f in the East direction. Since the orbital planes suffer a small shift in time, these inter-plane ISLs require switching from one satellite to other from time to time. Usually this task is performed twice every orbit period. For example, in a network in which, the orbit period is about 2 hours, a specific inter-plane ISL would last for something less than one hour.

Detailed Description Text (6):
The most dynamic inter-satellite links (ISL) are the cross-seam links 16g. Due to the crossing between the edge orbit planes, at the cross-seams at the polar regions, the satellites are in those orbits are moving in opposite directions. This means that the switching between satellites will be much faster. For the exemplary two hundred and eighty eight satellite model referred to above, a cross-seam inter-satellite link would last typically for 4.5 min, depending on the configuration of the system, having to perform a hand-over to the incoming satellite after this period.

Detailed Description Text (60):
If we look at the mean number of hops in time in FIG. 5, we appreciate that the average number of extra hops is close to 0.8 and stable in time, which means that on average the packets are going to use 0.8 more hops than the shortest path. The additional delay introduced by this small number of extra hops is negligible.

CLAIMS:

1. A system wherein each satellite within a said group has permanent inter-

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satellite links with its immediate neighbours in that group.

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